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Abstract

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EVALUATION OF RIFLE-FIRING BEHAVIOR OF TROOPS  
EQUIPPED WITH BODY ARMOR: A PILOT STUDY

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September 1972

HUMAN ENGINEERING LABORATORY



ABERDEEN PROVING GROUND, MARYLAND

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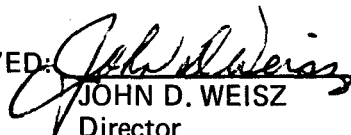
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Aberdeen Proving Ground, Maryland

### ABSTRACT

Twenty enlisted men, equipped with two types of body armor fired the M16 at pop-up targets. The range was electronically instrumented to record shots and hits, as well as relationships between these events. Each subject fired 180 rounds at targets which appeared for two, four and six-second presentation intervals. The results showed no significant difference between standard nylon vest, nylon titanium vest or no-vest conditions as subjects fired from the standing position. Further, it was evident that the shooter's performance during two-second presentations differed significantly from performance during four and six-second exposures. It was concluded that body armor alone does not affect rifle-firing behavior for either accuracy or firing time, that subsequent investigations need not include four or six second presentation times, and that further research on rifle-firing behavior should explore complete equipment ensembles, including load-carrying gear.

# EVALUATION OF RIFLE-FIRING BEHAVIOR OF TROOPS

## EQUIPPED WITH BODY ARMOR: A PILOT STUDY

### INTRODUCTION

The experiment described in this report is one of a number of current and projected investigations aimed at developing comprehensive criteria for the evaluation of life-support systems. As a participant in the U. S. Army Materiel Command (USAMC) Five-Year Technical Plan for Personnel Protective Systems, the primary responsibility of the U. S. Army Human Engineering Laboratory (HEL) is to provide a battery of standardized tests applicable to existing and prototype armor ensembles. The overall experimental approach shown in Figure 1 indicates that the standardized tests will ultimately be based on laboratory experiments and field studies, objective and subjective measures, and individual and group performances.

The infantryman and his rifle form a weapon system which must be an efficient combination of components on the battlefield. This weapons systems is neutralized if either the soldier or his rifle does not respond effectively in a crucial situation. As in any system, restrictions on any one component may influence total system effectiveness. Hence, any piece of equipment which may restrict the soldier in the act of firing his rifle may in fact interfere with system performance.

The USAMC Five-Year Armor Systems Technical Plan (1970) describes the requirement to investigate the infantryman's performance as a weapons system, while equipped with body armor. This requirement is based on two anticipated effects of the man/equipment interface: the individual's ability to hit the target while equipped with body armor; and, the effect of armor on his time to fire.

Accuracy of firing could be affected in many ways by existing body armor. Because of the bulky qualities of some ballistics materials, the shooter may not be able to "get the feel of the weapon" as he shoulders the rifle. Therefore, he may not shoulder the rifle at the same place for each shot. There may also be restriction of movement at the shoulder and at the arm pit as the shooter assumes the firing position. Further, the collar of the vest may interfere with "cheeking" the rifle and thus alter the sight picture. Finally, the added weight of the body armor could interfere in general with psychomotor performance and adversely affect aiming behavior.

Time to fire may be affected even more by body armor. If the soldier can hit the target, but requires more time to do so, it is possible that the delay could cause the shooter to become a casualty before he can fire. Since present armored vests are not "bullet proof," any added exposure to small-arms fire would increase the vulnerability of the soldier to the enemy rifleman. This added vulnerability is particularly important when the tactical concept of fire superiority is considered.

To evaluate the effect of present body armor on small-arms firing behavior, an investigation was conducted to determine to what extent body armor affects the effective employment of small arms by the soldier. In addition to hit-probability and time-to-fire data, a photographic record was made of several shooters to evaluate possible restricted movements and shooting form.

The overall purpose of this investigation was to determine the feasibility of using existing range facilities to evaluate the effects of body armor on rifle-firing behavior.

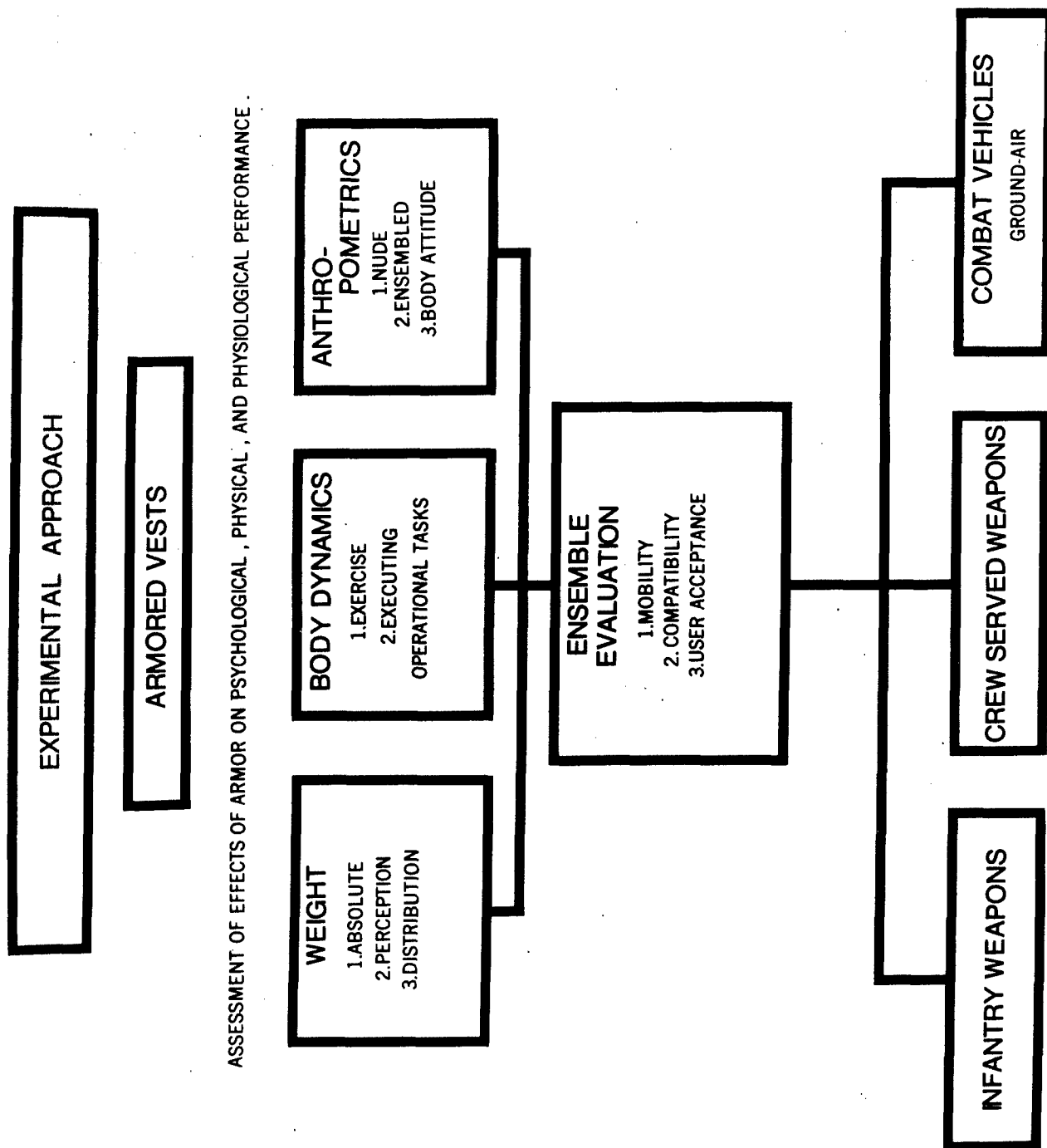


Fig. 1. GENERAL EXPERIMENTAL APPROACH TO BODY ARMOR EVALUATION

## METHOD

### Subjects

Twenty U. S. Army enlisted men, grades E2 through E4, served as subjects. Each subject had received Army Basic Training and had qualified with the M16 rifle.

### Apparatus

The experiment was conducted at M-Range, Aberdeen Proving Ground, Md. Five pop-up targets, electronically wired to record hits (Fig. 2) were situated in a 60-degree arc, 30 meters from a fixed firing point. A microphone, located near the firing point, provided a signal when impulse noise from the report of a rifle reached a level of 140 dB. A target controller located approximately 25 meters from the firing point was the center of the instrumentation system. A target-controller operator selected and initiated each target presentation by manually operating the appropriate target switch. Since the target presentation time was automatically controlled, only the inter-trial interval was dependent on a stopwatch manually controlled by the operator. This interval was held at 10 hundredths of a minute between each trial.

An event recorder received and recorded presentation onset, time of firing, time of hit, and presentation end.

The following sequence of events occurred on each test:

1. Operator selects one of five targets by pressing appropriate button.
2. Operator depresses target-presentation switch.
3. Event recorder runs.
4. Target appears.
5. Event record provides a target trace.
6. Event recorder records shot.
7. Operator starts stopwatch.
8. If hit, recorder marks, and the target goes down; if not hit, target goes down at presentation-time end. Event recorder stops.
9. Operator selects next target.
10. Operator monitors stopwatch.
11. At 10 hundredths of a minute, operator initiates the next target presentation.
12. The procedure is repeated for the appropriate number of shots.

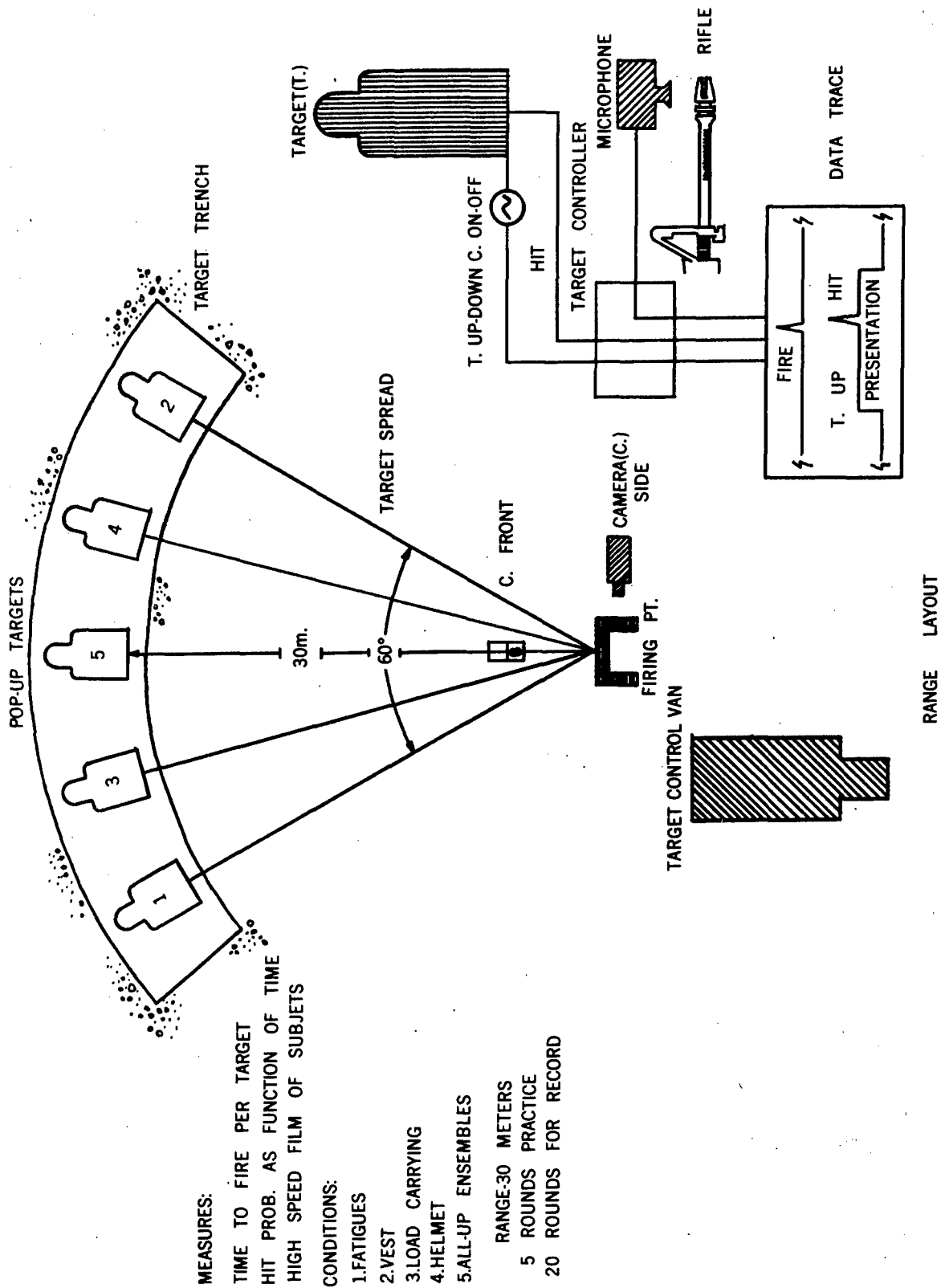


Fig. 2. HEL AUTOMATED POP-UP TARGET RANGE



## Procedure

Each subject was required to fire three conditions of 60 rounds each, one for each of three different armor vest conditions (i.e., standard nylon, nylon titanium vest and no vest). The order of firing for the three conditions was randomized to distribute any learning effects or environmental conditions across treatments. Additionally, subjects did not fire the three conditions consecutively nor was the period between each condition constant because of a high incidence of equipment malfunction — typically the firing for each subject was distributed across two days.

Within each vest condition, every subject fired 20 rounds at targets with two-second presentation times, 20 rounds at four-second targets and 20 rounds at six-second targets. Since five targets were used, each target was presented four times during each two, four and six-second condition. The order of target presentation was 30 degrees left of center (Target 1), 30 degrees right of center (Target 2), 15 degrees left of center (Target 3), 15 degrees right of center (Target 4) and dead center (Target 5). This presentation order was held constant across all time and vest conditions. The first five rounds of each target presentation condition were considered practice rounds and not included in the experimental data.

The following instructions were given to each subject after he had been fitted in the appropriate armor vest for a given vest condition:

"On my command you will pick up your weapon and assume a comfortable standing position. Here is a 20 round magazine. Lock and load at my command. You are to fire one round at each target. The target will be visible for (two, four or six) seconds. Be sure you get one round and only one round off for each target. You must hold your weapon at port arms before each shot. The targets will appear in this order. (The subject was shown where each target would appear). The cameras located here and here (front and side) should not concern you. Do you understand your instructions? Pick up your weapon and assume a comfortable standing position. Lock and load. Safety off. Are you ready? Fire when the targets appear."

## RESULTS

Using analysis of variance (ANOVA) for repeated measures across all variables, the time-to-fire data were evaluated (Table 1). The analysis shows statistically significant interactions between vests and shooter ( $F = 2.13$  df 38/76,  $p < .01$ ) and target time and shooters ( $F = 4.13$ , df 38/76,  $p < .01$ ). Two significant main effects, target exposure time ( $F = 690.55$ , df 2/76,  $p < .005$ ) and shooters ( $F = 3.9$ , df 19/76,  $p < .01$ ), were found, while the third variable, vest conditions was non-significant.

TABLE 1

## ANOVA Summary Table for Time-to-Fire Data

Source	df	SS	MS	F
Vest	2	.13	.06	1.56
Target Exp. Time	2	24.86	12.43	690.55*
Shooters	19	7.10	.37	3.90*
Vest x Tgt Time	4	.04	.01	.56
Vest x Shooters	38	1.46	.038	2.13*
Tgt Time x Shooters	38	2.83	.074	4.13*

\*  $p < .01$

A one-way analysis of variance was performed on the hit-probability scores across presentation times (Table 2). This analysis showed a significant presentation time effect ( $F = 27.73$ ,  $df$  8, 152  $p < .005$ ). Duncan's multiple comparison technique was applied to the data. The results of this test revealed a significant difference between the two-second presentation time, and the remaining presentation times (four and six seconds). The four and six-second conditions did not differ significantly from each other.

The films of several shooters were evaluated qualitatively. While these results are not easily reduced to quantitative scores, several interesting problem areas were identified. These areas will be discussed in later sections of this report.

TABLE 2

## ANOVA for Hit/Miss Data Across Presentation Times

Source	df	SS	MS	F
Total	179	15,098.977		
Subjects	19	4,437.348		
Time	8	6,327.531	790.941	27.73*
Error	152	4,334.098	28.513	

\*  $p < .005$

## DISCUSSION

The results of this investigation suggest that the two armor-vest configurations tested do not differ significantly from a no-vest condition as far as time to fire and hit probability are concerned. However, it should be pointed out that the vest is only one of many equipment items the infantryman may carry. The interface of body armor with load-carrying gear and other infantry accouterments may cause performance decrements not apparent from this investigation. These possible interactions are the subject of on-going research.

Other findings of this experiment are important to the development of methodology for future research in this area. The significant difference between the two-second and other target presentation times, coupled with the non-significance between four and six-second presentation times, indicates that subsequent investigations can be confined to the two-second time frame. Additionally, it is apparent that subsequent experiments should be designed to more effectively describe and evaluate the interactions which appeared in this investigation.

The use of photography to qualitatively describe rifle-firing behavior of the individual while equipped with body armor adds another important dimension to methodological development. While the vest configurations were not statistically significant, the films of selected shooters show several possible shortcomings in present body-armor configurations. Several shooters were seen to appreciably alter their shooting form to accommodate the bulk of the vest. It was apparent from the films that many shooters placed the butt of the rifle at a different location on the shoulder for almost every shot. Further, it was noted that some subjects frequently snagged the rear sight of the rifle on the Velcro or zipper flap of the vest. To accommodate for this interference some shooters thrust the rifle butt out away from their body. This behavior indicates a learning effect which should be assessed in future research.

## SUMMARY AND CONCLUSIONS

The task of evaluating firing behavior of soldiers equipped with body armor was approached by using an electronically-controlled pop-up target system capable of providing time-to-fire and hit-or-miss data. Presentation times of two, four and six seconds were used to determine an effective presentation interval. The findings indicate no statistical differences between no vest, standard nylon vest and titanium nylon vest conditions. Further, it was concluded that continued use of photography is warranted, that target presentation times should be held to two seconds, and that an experimental design better suited to describing shooter versus vest and shooter versus target time interactions should be used.

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13. ABSTRACT <p>Twenty enlisted men, equipped with two types of body armor fired the M16 at pop-up targets. The range was electronically instrumented to record shots and hits, as well as relationships between these events. Each subject fired 180 rounds at targets which appeared for two, four and six-second presentation intervals. The results showed no significant difference between standard nylon vest, nylon titanium vest or no-vest conditions as subjects fired from the standing position. Further, it was evident that the shooter's performance during two-second presentations differed significantly from performance during four and six-second exposures. It was concluded that body armor alone does not affect rifle-firing behavior for either accuracy or firing time, that subsequent investigations need not include four or six second presentation times, and that further research on rifle-firing behavior should explore complete equipment ensembles, including load-carrying gear.</p>			

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